

HYD 227

HYD-227

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

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TESTS ON SPARKING METERS--INITIAL STUDY OF A
6-INCH METER--COACHELLA DISTRIBUTION SYSTEM
ALL-AMERICAN CANAL PROJECT, CALIFORNIA

Hydraulic Laboratory Report No. Hyd. 227

ENGINEERING AND GEOLOGICAL
CONTROL AND RESEARCH DIVISION



BRANCH OF DESIGN AND CONSTRUCTION
DENVER, COLORADO

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Branch of Design and Construction
Engineering and Geological Control
and Research Division
Denver, Colorado
January 2, 1947

Laboratory Report No. 227
Hydraulic Laboratory
Compiled by: D. Colgate and
F. C. Lowe
Reviewed by: H. M. Martin

Subject: Tests on sparring meters--Initial study of a 6-inch meter--
Coachella distribution system--All-American Canal Project,
California.

INTRODUCTION

Irrigation has changed the Coachella Valley in California from a desert to one of the richest agricultural districts in the state. At present the water is obtained from wells by pumping, but upon completion of the Coachella branch of the All-American Canal, water will be available from the Colorado River. This increased and more economical supply will put many additional acres of land under cultivation. Because of high land values and because of the nature of the topography, the distribution system from the main canal is to be piping. One important problem in this distribution system is the selection of a satisfactory method of measuring discharge. In tests described in Laboratory Report HYD 175, "Hydraulic model studies of measuring devices for the Coachella Distribution System," and Laboratory Report HYD 202, "Pipeline orifice studies, Coachella Distribution System," several devices were studied, one using an alfalfa valve, three using various types of weirs, and one involving orifices in the line. Each of these methods are undesirable in certain respects under conditions found in the Coachella Valley.

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INTRODUCTION

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The Sparling Main-Line Meter (Figure 1) has been proposed for the distribution system. This meter, a commercial type, consists of a multibladed propeller geared to a totalizer in such a manner as to indicate the total flow in cubic feet, acre-feet, or other desirable unit. It is manufactured in five different types to accommodate pipe sizes from 2 to 72 inches. In three types the meter is placed in short tubes designated as a threaded tube, flanged tube, or bell and spigot tube, depending upon the pipe connection. The two other types, one using a saddle and the other a wing and U-bolt arrangement, are for installation in existing lines where a tube could not be placed. The normal flow range of this meter is 1 to 10; that is, the maximum recommended discharge is 10 times the minimum accurate discharge. A special compound meter with a flow range of 1 to 100 is also available. Propellers for the meter are six bladed, made of moulded plastic or aluminum alloy, and are approximately .8 the nominal pipe diameter. Tube-type meters have a brass lining and the smaller sizes include flow straightening vanes. As manufactured, the totalizer is set on the pipe at the meter, but may be moved as much as 15 feet from the meter by an extension cable. By electrical controls the totalizer may be combined with an indicator or recorder and installed in any convenient location.

The advantages claimed for this meter are its use in various types and sizes of pipe, simplicity of construction, direct reading of the totalizer, accuracy, low line loss, durability, and simplicity of repair. The Bureau of Reclamation has had little experience with the Sparling meter. Some propeller-type meters used by the Bureau

have not been entirely satisfactory because of the propeller becoming fouled with moss and because of bearing wear. The dearth of information on this type of irrigation water measuring device made it apparent that laboratory tests as well as field tests were necessary and desirable.

For a preliminary study a 6-inch flanged tube meter was procured on a loan basis from the R. W. Sparling Company, Los Angeles, California. The totalizer of this meter was calibrated to read in units of 10 cubic feet.

Summary of Tests

This initial study was concerned only with the determination of the accuracy of the meter. The manufacturer's published circulars indicating that the accuracy is within 2 percent; that is, the measured flow will vary between 98 and 102 percent of the actual flow. Tests showed the accuracy of the studied meter varied from 97.3 to 101.5 percent. It was demonstrated that for the same discharge the accuracy would vary from 97.3 to 100.5 percent when the line pressure was increased. The exact nature of these variations of accuracy with discharge and with line pressure cannot be determined without testing a number of meters to subordinate the individual differences found in each meter.

Recommendations

It was concluded that this meter was accurate within 2 percent as claimed by the manufacturers. However, further tests are recommended to determine the meter characteristics of a representative sample for the various sizes likely to be used in numbers in irrigation work. It would be desirable to test several meters which have been

in use over a long period of time to determine the effect of wear on the accuracy. It is believed that the meter might be satisfactorily used where it was necessary to obtain an accuracy better than 2 percent if the characteristics of the meter were fully known; that is, the relations of accuracy to discharge and to line pressure.

Laboratory Arrangement and Test Procedure

The 6-inch meter was installed horizontally in a line between the laboratory pumps and calibration tank. To insure proper velocity distribution at the meter, a straight pipe 8 feet 1 inch long was placed upstream from it and a pipe 5 feet 7 inches long was placed downstream. This gave an approach length of 16 diameters which should be adequate in light of the fact that the manufacturer recommends a minimum approach length of 8 diameters. Two control valves were used, one between the meter and the pumps, and the other at the calibration tank. With these valves it was possible to regulate both pressure and discharge. The calibration tank, with a capacity of 405 cubic feet, was part of the laboratory equipment. It was filled by a mechanically operated swing-spout which could be directed either into the tank or into a bypass pipe (Figure 2A).

In preliminary runs the testing procedure was established. The swing-spout was directed into the bypass pipe until the flow through the meter was stabilized. Then an operator at the calibration tank, through a control lever, shifted the swing-spout into the calibration tank and at the same time started a stop watch. Simultaneously another operator at the meter read the totalizer. When the tank was filled, the swing-spout was shifted back into the bypass, the time

recorded by the stop watch, and another reading made on the totalizer. Computations were made for each run to determine the accuracy of the meter; that is, the ratio of the volume indicated by the totalizer to the tank volume. This method was not sufficiently accurate because of the difficulty of reading the totalizer simultaneously with the swing of the swing-spout.

To insure a simultaneous reading of the totalizer with the start and stop of the flow of water into the calibration tank, a camera was mounted directly above the totalizer and connected electrically through a synchronizer to a mercury trip switch at the calibration tank. (Figure 2A, and Figure 3A.) With this arrangement the shutter of the camera was opened at the same instant the swing-spout touched the trip switch. An accurate reading of the totalizer could be obtained from the resulting photograph. To determine period of run, a watch was mounted next to the totalizer in such a manner as to be included in the picture. This method eliminated the human factor in the readings, and provided a permanent record of the initial data. For photographs and computations of a typical run, see Figure 3B.

Relation of Accuracy to Discharge

The first test consisted of 30 runs in which the accuracy of the meter was measured for discharges from 0.083 to 3.358 second-feet. The corresponding mean velocities through the pipe ranged from 0.42 to 17.10 feet per second. In these runs the actual discharge, indicated discharge, and duration of run were measured in the manner described above. It was also planned to measure the head loss of the meter, but this was prevented by a defective piezometer in the line, which was not

discovered until the tests were begun. The results of this test, the relation of accuracy of the meter to discharge or velocity, are shown on Figure 2B. The curve represents the mean of the scattered points. A typical accuracy curve for a 6-inch tube-type meter, as taken from the manufacturers Drawing No. 325-9982, is shown on Figure 2B as a dotted line. Two tests by the manufacturers on the same meter as tested in the Hydraulic Laboratory of the Bureau, are also shown on this figure. It is to be noted that the data obtained by the Bureau indicated an average meter accuracy of about 99 percent, while that of the manufacturer indicated an accuracy of about 101 percent. No explanation for this difference was suggested. It was pointed out that there was a difference in the method of calibration in that the manufacturers used a quick acting valve to control the flow into their calibration tank, whereas the Bureau laboratory used a swing-spout to permit the flow to stabilize before turning it into the calibration tank. However, it can be shown that any difference from these two methods would be opposite from the results obtained. It is understood that the factory tests were made without any lubricant in the meter. Before the meter was sent to the Bureau laboratory it was packed with a special grease. If this grease tended to increase the friction on the bearings it would explain the lower values obtained by the Bureau laboratory.

The scattered erratic nature of the data was questioned. Since the loss of head was not measured, the line pressure was also not measured because both the manufacturers and the engineers of the Bureau tacitly assumed that the line pressure would have no effect

upon the accuracy. In the final three runs, however, the same discharge was used for high and low heads. The results showed that the accuracy varied from 97.8 percent for a low head to 100.9 percent for a high head.

Relation of Accuracy to Line Pressure

When it was demonstrated that the line pressure had an appreciable effect on the accuracy of the meter, a test was made to show the relationship of accuracy to line pressure for discharges of 0.355, 1.002, and 1.732 second-feet, and for heads between 6.1 and 91.3 feet of water. The curves of Figure 20 show an appreciable variation of accuracy with line pressure. For the discharge of 1.002 second-feet the accuracy was 97.3 percent at a head of 6.1 feet, 98.5 percent at a head of 25 feet, 100.6 percent at a head of 58.5 feet, and 99.1 percent at a head of 86 feet. The curves for other discharges were similar, and from this data it might be concluded that the accuracy would vary from 97.3 percent to 101.5 percent. The cause of this variation of accuracy with line pressure can not be explained from this test, and since it was necessary to return the meter to the manufacturer, no further tests were made.

Theory of Propeller-Type Meter

If an extended study of this type of meter were to be made it would be desirable to have a rational analysis to compare the data. This section is presented as a proposed step in the development of such an analysis, the basis of which is reasonably valid for cases where the line pressure is held constant. It is possible to show

that the accuracy of the meter is restricted by its own mechanism, that the accuracy curves obtained by the manufacturers have a theoretical basis, and that if the period of operation of the meter is known a correction factor may be applied to the reading of the totalizer.

Flow measurement devices for closed conduits may, generally, be classified into three groups: those which measure the dynamic pressure force of the fluid; those which use the movement of the fluid to drive an impeller; and those which use volumetric and weighing devices. It is the second group with which this discussion is concerned, which includes current meters, anemometers, and propeller meters such as the Sparling meter. In instruments of this type, a definite relationship exists between the velocity of the fluid and the rate of rotation of the propeller or vanes. Plotted in rectangular coordinates this relationship becomes very nearly a straight line which for purposes of this discussion may be expressed as $V_a = aR + b$ (see Curve A of Figure 4A), where V_a is the actual velocity of flow, R is the speed of rotation of the propeller, a is a constant representing the relation between the change of velocity to the change of speed of the propeller, and b is a constant representing the initial velocity required to overcome the frictional resistance of the propeller.

In calibrating a current meter or anemometer the problem is essentially to determine the constants a and b . In the use of these meters, the procedure is the determination of the rate of rotation of the propeller or vanes and reference to a table or graph giving

velocity-propeller speed relationships. Careful measurements with a good instrument will give very accurate results. In the Sparling meter, however, the mechanism for recording the flow is based upon a different precept and similar accuracy cannot be obtained. The total flow is recorded by the totalizer which essentially counts the revolutions of the propeller, although it is calibrated to read in cubic feet or gallons. It follows that the measurements so obtained do not depend upon the velocity of flow but will record the same quantity for a given number of revolutions of the propeller regardless of the rate of delivery. With the totalizer geared to the propeller, the indicated relation of velocity to rotation of the propeller might be expressed as $V_i = AR$ (Curve B of Figure 4A). Since, the true relation is shown by the Curve $V_a = aR + b$, the indicated curve must be in error. To minimize this error, the value of the constant A of Curve B is so selected as to cross Curve A at a discharge where the meter will most likely be used in normal operation. From these curves, it follows that the error is large at low velocities, decreasing to zero at the normal velocity, and approaching a constant factor as the velocities increase further.

The manufacturers have experimentally determined curves to show the accuracy of the meter for various velocities (or rates of discharge), where the accuracy, in percent, is the ratio of the indicated discharge to the actual discharge. (Curve A of Figure 4B).

The curves of Figure 4A would suggest that a similar curve to show the accuracy of the meter might be obtained from the expression

$$K = \frac{V_n(V_a - b)}{V_a(V_n - b)}, \text{ where } K \text{ is the accuracy relationship, } V_n \text{ is the velocity}$$

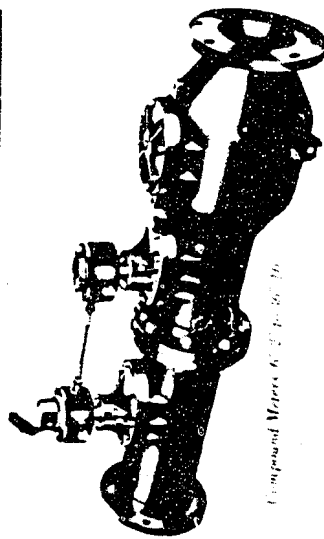
of normal flow, and the other values are as previously stated. Curve B of Figure 4B was drawn in this manner by using arbitrary values of b and V_n without reference to any particular meter.

If the curves as shown in Figure 4A can be verified experimentally, it follows that a simple correction factor may be applied to the indicated reading of the meter if the period of the run is known. Let the indicated discharge $Q_i = \int v_i \Delta t$, and this quantity recorded by the totalizer. Now at any instant the actual discharge is $\Delta Q_a = \frac{\Delta Q_i}{K} = V_a \Delta t = \frac{V_i}{K} \Delta t$. It was shown that $V_a = aR / b$, and $V_i = AR$. The value of A depends upon the ratio of the gears from the propeller to the totalizer. Assume that this ratio is changed by the factor $\frac{a}{A}$ so that $V_i \cdot \frac{a}{A} = aR$, (Curve C, Figure 4A). Then the error function becomes $K = \frac{\frac{a}{A} V_i}{aV_i / b}$, and the expression $\Delta Q_a = \frac{V_i \Delta t}{K} = (V_i / b) \Delta t = (\frac{a}{A} V_i / b) t$, or $Q_a = \frac{a}{A} V_i t / b$, but this quantity is equal to the reading of the totalizer modified by the factor $\frac{a}{A}$, plus the quantity $b \cdot T$ where T is the time of the run.

ACCURATE - DURABLE



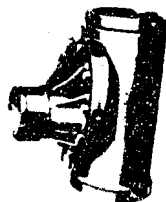
Large Type Meters
2" to 3"



Compound Meters 6" to 36" Dia.



Flanged Tube Meters
6" to 36"



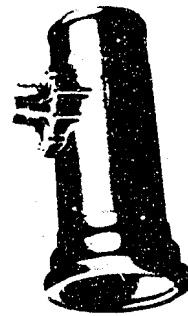
Meters in Integral
Cast Steel Tubes
2" to 6"



Saddle Type Meters
Bolted or Welded to Pipe
6" to 72"



Meters for Use on
Concrete Pipe
6" to 72"



Bell and Syphon Meters
1" to 6"

There is a
Type and Size

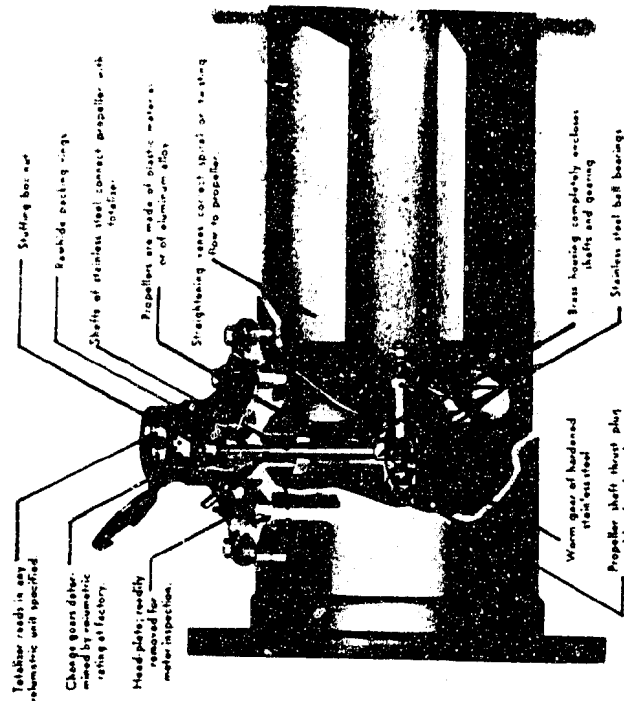
SPARLING

Main-Line Meter

to meet your requirements for accurate
water measurement.

Sparling tube meters are as easily installed as a valve
or fitting in the line. Compound meters are available
where accuracy over a very wide range of flow is de-
sired. Saddle type meters are in at readily mounted
on lines already in place.

METERS FOR MAIN LINES



All Sparling Meters, tube or saddle mounted—operate on one easily understood principle, clearly explained by this cutaway view. Flow here is from right to left though meters do register on reverse flow nearly as accurately.

OPERATING PRINCIPLE

A six-blade propeller rotates in the stream in direct ratio to the volume of water passing through the meter. Shafts and gears carry the revolutions to the Totalizer. No round about steps!

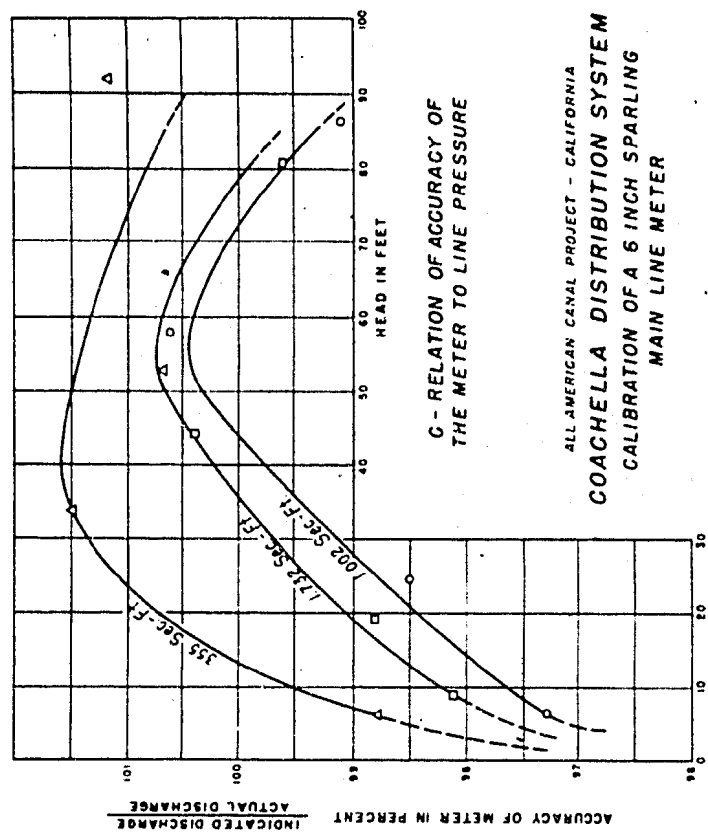
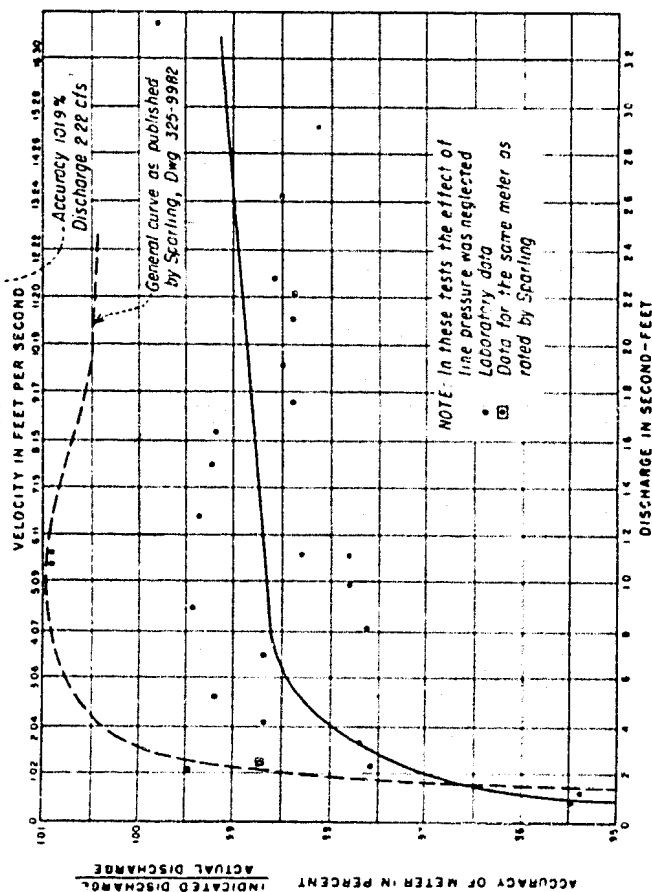
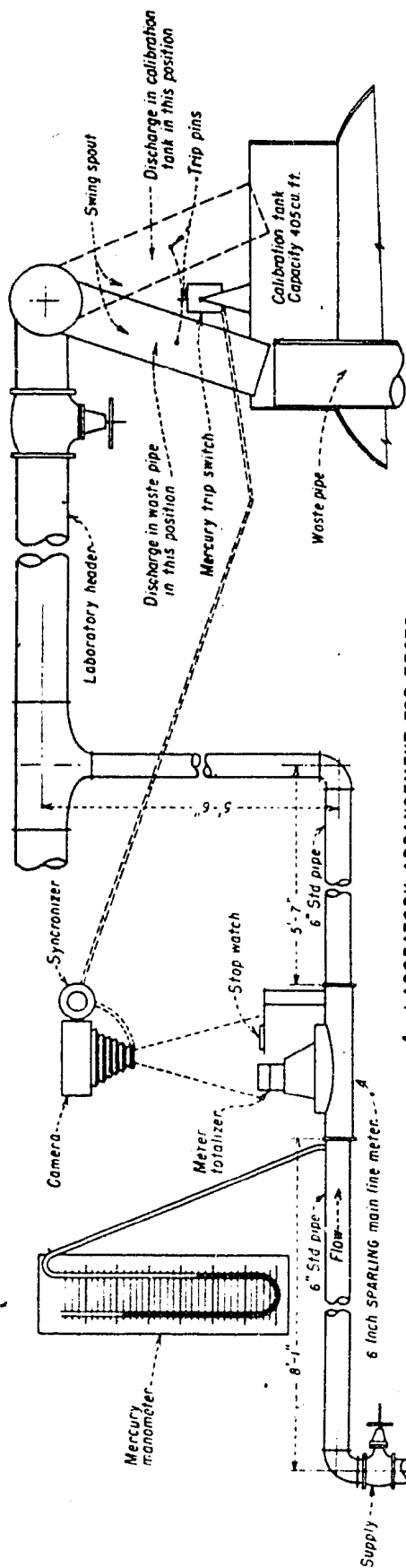
The propeller is eight-tenths pipe diameter and transmits nearly the entire flow force. Its rotation is unaffected by eddies, swirls, or by the flow veering to one side of the pipe, but jet effect from a partly closed valve or similar obstruction close ahead of the meter should be avoided.

The force of the stream gives so much greater "power" to the propeller than is required to operate the totalizer, indicator, and recorder, that reflection of the accuracy curve due to friction is less than one per cent over a one-to-ten flow range.

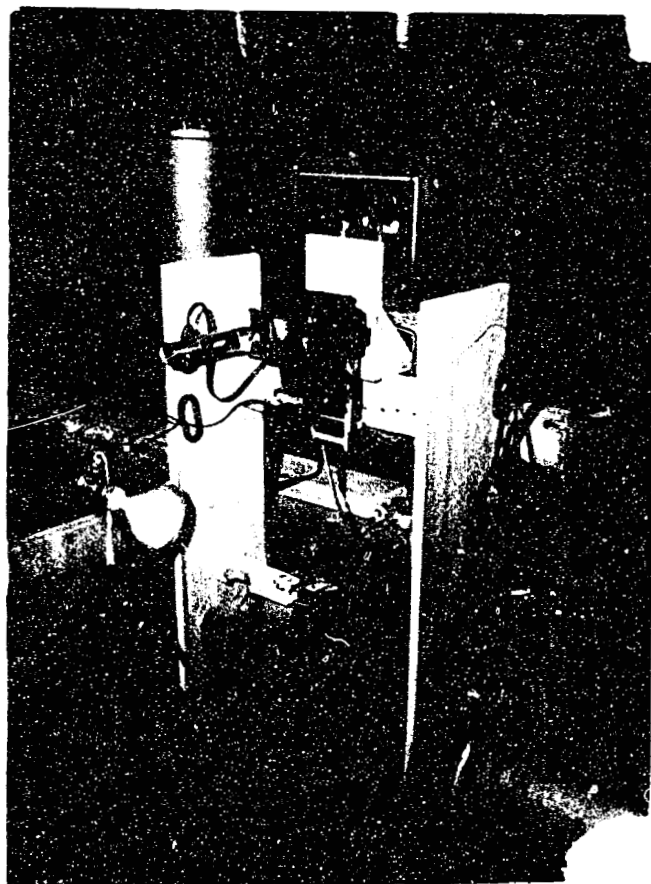
All the meter needs for consistent accuracy up to any rate within reason is a full pipe of water, a normal flow movement through the propeller, and a velocity above the specified minimum.

SPARLING

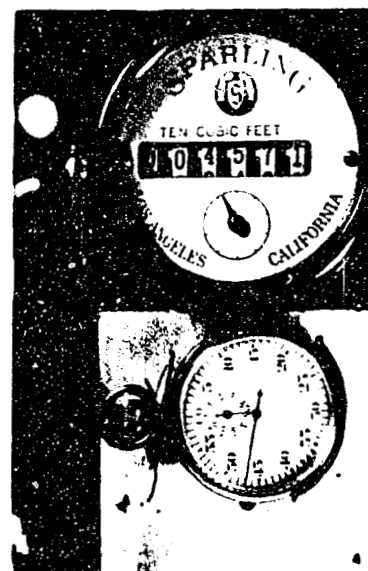
SPARLING



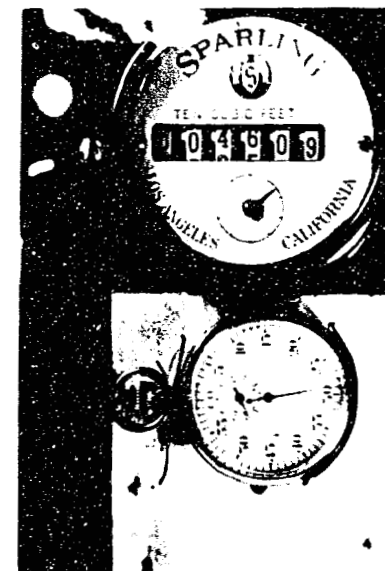
ALL AMERICAN CANAL PROJECT - CALIFORNIA
COACHELLA DISTRIBUTION SYSTEM
 CALIBRATION OF A 6 INCH SPARLING
 MAIN LINE METER



A. Installation of a 6-inch Sparling main line meter in the Bureau of Reclamation hydraulic laboratory for the purpose of conducting accuracy tests. The camera, synchronizer, and stop-watch were used to obtain instantaneous readings.



Meter - 45709.2
Watch - 14: 47.0



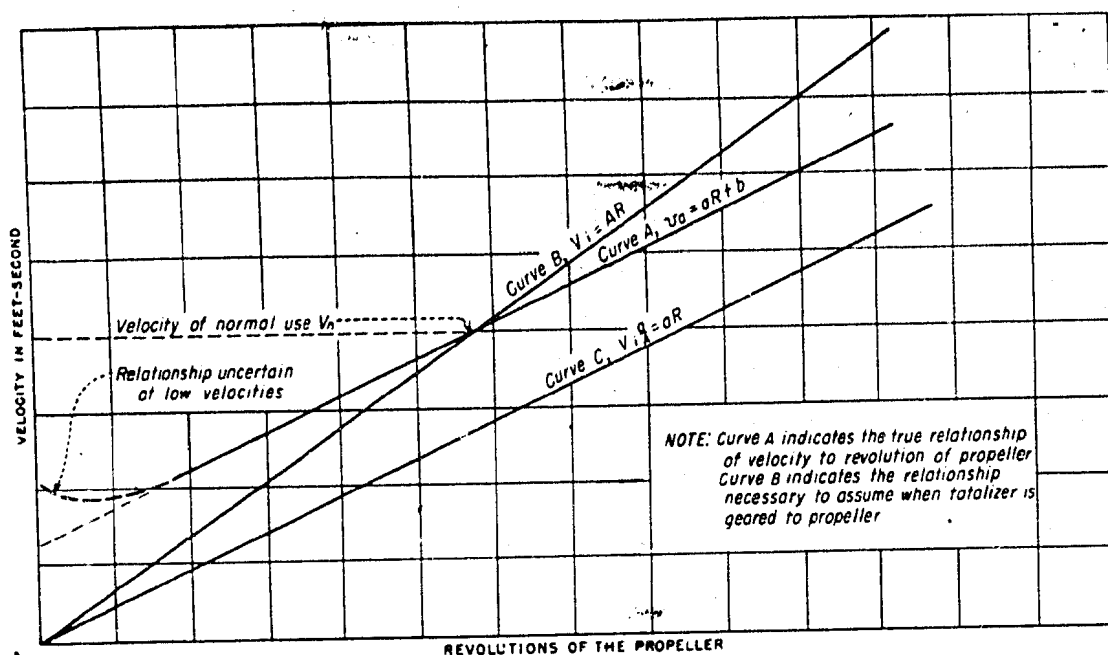
Meter - 46091.5
Watch - 20: 29.0

Tank Volume		378.7 cu. ft.
Meter Difference		382.3 cu. ft.
Watch Difference		342.0 seconds
Discharge	$\frac{378.7}{342.0}$	1.107 c.f.s.
Meter Accuracy	$\frac{382.3}{378.7}$	100.9%

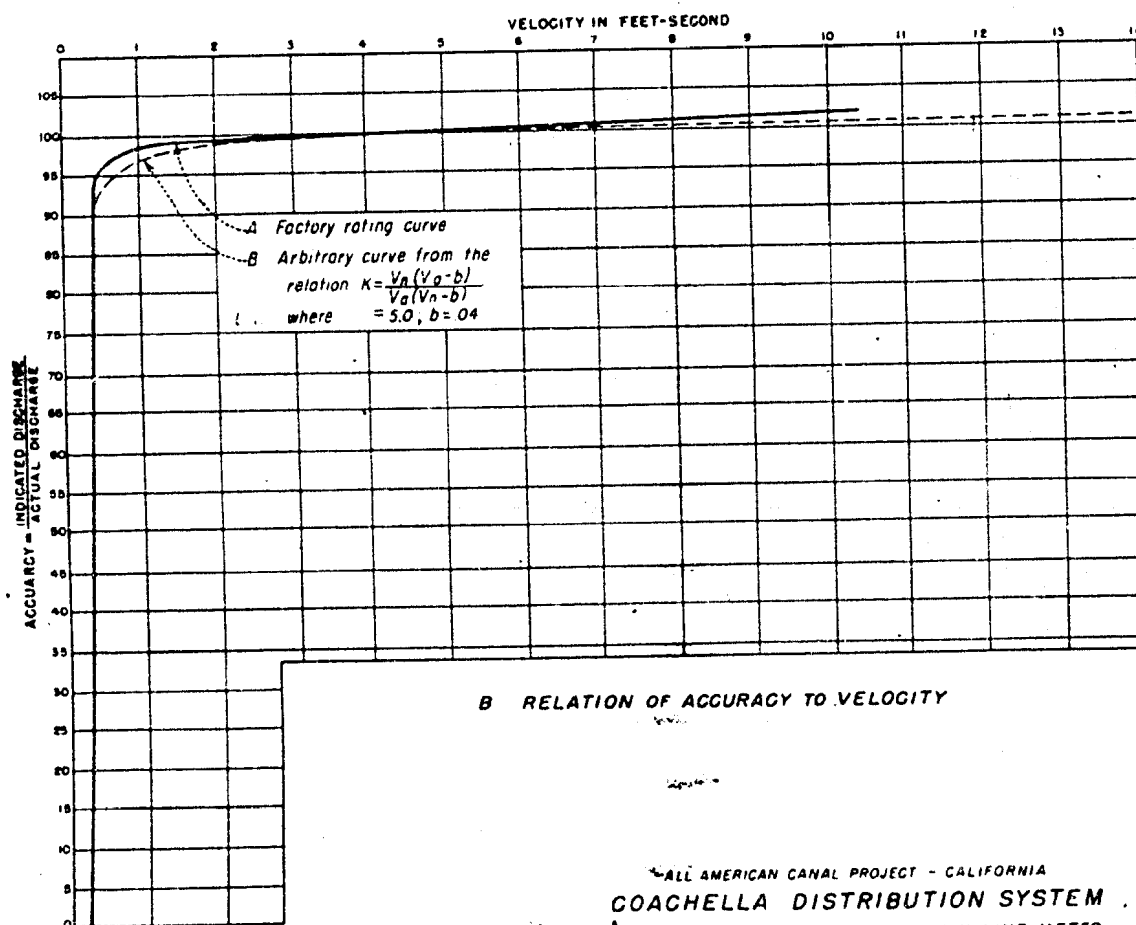
B. TYPICAL COMPUTATIONS

ALL AMERICAN CANAL PROJECT CALIFORNIA
COACHELLA DISTRIBUTION SYSTEM

TESTS ON SPARLING METER



A RELATION OF VELOCITY TO REVOLUTIONS OF THE PROPELLERS



B RELATION OF ACCURACY TO VELOCITY

ALL AMERICAN CANAL PROJECT - CALIFORNIA
 COACHELLA DISTRIBUTION SYSTEM
 TESTS ON A 6-INCH SPARLING MAIN LINE METER
 BASIC RELATIONS OF VELOCITY AND ACCURACY OF METER